‘I’m sad that it’s gone’: a case study of teachers’ views on teaching the nature of science at key stage 4

Richard Brock and Keith S. Taber

Abstract The current climate, in which some politicians reject widely accepted scientific claims, suggests that teaching the nature of science should be a significant aspect of science education. This case study, of six English secondary teachers in a single science department, reports their concerns about the marginalised role of the nature of science in the English key stage 4 curriculum (ages 14–16). The teachers’ comments suggest that curriculum statements related to the nature of science can be interpreted in different ways and, therefore, more guidance is required to support teachers’ understanding of areas of consensus and controversy in the nature of science.

The value and challenges of teaching about the nature of science

The current political climate has been labelled the ‘post-truth era’, referring to some commentators’ perceptions that scientific claims are deliberately disregarded by certain politicians, are attacked by media commentators, and have limited influence on public opinion. This context suggests that teaching students about the nature of scientific claims and the processes of knowledge-generation used by scientists, which are often collectively referred to as the nature of science (NoS) (Taber, 2017), is of particular importance at the present time. Although what NoS-related content should be taught in schools is controversial, students, regardless of whether they choose to study science subjects in post-compulsory education or not, should be supported to understand the arguments made by policy makers and to make decisions related to health, the environment and consumption by developing an understanding of the NoS (Taber and Brock, 2018).

Recent decades have seen several changes to National Curriculum statements in England and Wales related to the NoS. However, the manner in which teaching about the NoS is implemented in practice may differ from curriculum designers’ intentions for a number of reasons (Benson, 1989), so it is not sensible to assume that what is taught directly reflects curriculum statements. First, much research has indicated that teachers’ views on the NoS differ from those of philosophers of science (Abd-El-Khalick and Lederman, 2000) and hence teachers’ interpretations of curriculum statements related to the NoS may be shaped by their own beliefs about the NoS. Second, when planning lessons, teachers engage in a decision-making process in which they select teaching approaches that emphasise some aspects of the curriculum and, by constrast, neglect others. While teachers’ beliefs about the NoS have been well researched (Abd-El-Khalick and Lederman, 2000), little has been written on how teachers interpret and implement curriculum statements related to the NoS in their practice. The latest iteration of the English key stage 4 (ages 14–16) programme of study (DfE, 2015) has again seen a change in emphasis on the position of the NoS in the curriculum, as happened with previous versions.

This article presents data from a small-scale study that reports six science teachers’ views on the role of the NoS in the programme of study and describes their approaches to teaching about the NoS.

Teachers’ enactment of curriculum statements related to the nature of science

The implementation of curriculum statements can be conceptualised as an interpretive act. Different teachers may plan lessons with different foci and activities intended to address the same learning objectives. Arguing from a constructivist point of view, Benson (1989) proposed that curricula should not be seen as fixed bodies of knowledge, but as constructs that are shaped by the social activity in a context and by individual teachers’ personal beliefs. Teachers make inferences about curriculum designers’ intentions, and prioritise, interpret or neglect material depending on their personal beliefs and the particular cultures of the schools and departments in which they are working. The manner in which teachers implement, ignore or make sense of policy documents has been referred to as enactment (Ball, Maguire and Braun, 2012).

Enactment might be considered as having two aspects: the meaning that a teacher infers from a

curriculum statement and the decisions that they make regarding appropriate approaches for implementing that statement in their classroom practice. For many statements on the science programme of study, the scope for alternative interpretations is limited. For example, it might be assumed that most science teachers would have similar interpretations of the statement: '*Students should be taught about … power as the rate of transfer of energy*' (DfE, 2015: 14). However, different teachers may choose different teaching approaches to explain the concept of power to their students.

By contrast, some curriculum statements related to the NoS allow greater scope for variation in enactment. Like scientific content knowledge statements, NoS objectives may be taught using a variety of different approaches, but the statements can also be interpreted in different ways. For example, in the statement that '*students should be taught so that they develop understanding and first-hand experience of … the power and limitations of science*' (DfE, 2015: 5), the nature of the limitations of science may be conceptualised differently by individual teachers. A teacher who holds a scientistic interpretation of science might believe that scientific principles can be appropriately applied to social and ethical questions and may, explicitly or tacitly, plan activities that promote this view in their classroom. Another teacher might believe that the knowledge claims produced by science are tentative and that the scientific method may only be used to address certain questions related to the physical world. The second teacher will enact the curriculum statement in a different manner from their more scientistic colleague.

Currently, little research has examined how teachers come to develop their own interpretations of curriculum statements related to the NoS and how they make decisions about appropriate teaching approaches for delivering NoS content. It has been reported that some teachers are apprehensive about teaching the NoS because they believe it requires different pedagogies from those used to teach other scientific content (Ratcliffe, 1997). For example, the curriculum statement that requires that students are taught to understand '*the ways in which scientific methods and theories develop over time*' (DfE, 2015: 5) might be interpreted to entail pedagogies that encourage students to consider different interpretations of historical events. A teacher introducing Galileo's role in the increasing acceptance of the heliocentric model of the solar system, for example, may choose to describe the different ways in which the historical events have been interpreted.

Science teachers' beliefs about the purpose of school science are likely to influence the manner in which they interpret the curriculum. For example, teachers may choose to place less emphasis on material that is perceived to involve matters of opinion (Gayford, 2002) or may believe that socio-scientific content is optional (Hughes, 2000).

The case study

This study set out to investigate the question: What influences the manner in which science teachers enact curriculum statements related to the NoS? The project focused on the key stage 4 programme of study as it was hypothesised that recent curriculum reforms have led to changes to teaching about the NoS in GCSE (the public examination taken at age 16) science.

Data collection

A convenience sample of six secondary science teachers, all teaching at a single school in England, with a range of specialisms and years of experience was selected (Table 1). It is reported that teachers' pedagogic content knowledge, their beliefs about the effectiveness of different teaching approaches, is influenced by their level of classroom experience (Clermont, Borko and Krajcik, 1994) and that enactment may be influenced by cultural factors such as membership of particular teacher cultures (Benson, 1989). Given that teachers working together in one science department are likely to influence each other's practice, the study is conceptualised as a single case study of enactment in the context of one science department. This conceptualisation coheres with an analysis that constructs common themes across participants. The identities of the school and teachers have been anonymised. Participants are referred to by gender-appropriate pseudonyms. The participants volunteered to be interviewed, having being briefed about the purpose of the study.

All six teachers worked at an 11–18 academy (that is, a secondary school) with above-average student achievement both on the Progress 8 measure (a value-added metric of student achievement at age 16) and on the percentage of students attaining grade 5 or above on their English and mathematics GCSEs. A semi-structured interview that allowed emerging themes to be probed while ensuring some degree of comparison between responses to questions from each participant

Table 1 Years of experience and specialism of participating teachers

Teacher	Years of experience	Specialism
Alan	26	Chemistry
Beth	9	Biology
Claire	1	Biology
Dawn	5	Biology
Ethan	6	Chemistry
Fiona	30	Physics

was used to prompt discussion about teaching the NoS at key stage 4. Given that the study was undertaken in one teaching context, generalisability of the data to other settings cannot be assumed, but the findings may offer insights of relevance to teaching in other English secondary schools (Taber, 2000). The interviews were audio-recorded and then transcribed. The transcripts were coded to mark sections that were interpreted as representing emerging themes, which are discussed below.

Teachers report the value of teaching about the nature of science

All the participants reported that they valued teaching about the NoS. For example, Alan referred to the NoS as the '*most important and valuable bit of science that you could teach anybody, whatever they were going to do*' and commented that:

> *We have politicians who make assertions which are not based on facts … The nature of evidence, the importance of evidence is denied in lots of aspects … as teachers we should be upfront that we think evidence is important and science has got to be part of that conversation.* (Alan)

Claire argued that, rather than just teaching the information required to pass exams, students should be taught '*the whole science*' through discussion of the NoS that might inspire a love of the subject. While Dawn echoed this claim, with an argument that teaching about the NoS develops students' understanding and interest, she also acknowledged that teaching students to memorise facts was easier than introducing ideas about how scientific ideas develop. Despite a general enthusiasm for teaching about the NoS, all the teachers reported a reduction in emphasis on content related to the NoS following the implementation of the last curriculum revision. For example, Alan claimed that '*really nowhere in the new GCSE curriculum is there any explicit teaching of the nature of science … it's just gone completely, almost overnight*'. The teachers described a number of barriers to implementing teaching about the NoS.

The current GCSE curriculum offers limited opportunities to teach about the nature of science

There was a consensus among the teachers that the latest version of the GCSE specification had seen an increased expectation on students' knowledge acquisition and a reduction in emphasis on ideas related to the NoS in comparison with previous curricula. For example, Beth remarked that '*Biology seems to be very content focused … it'd be good to have like more time to do the "how science works"*'. The difficulty of covering all the required knowledge resulted in a situation in which, Beth argued, material about the NoS was considered '*bonus content*'. Fiona lamented the loss of opportunities to discuss the historical development of scientific ideas because of the content-heavy curriculum and argued that students ended up learning facts at the expense of an overview of the NoS. Ethan felt that the new curriculum created a pressure to move quickly through the specification and that there was no time for teaching about the NoS. All the teachers reported that they took opportunities to teach about the NoS but the decision to include NoS material was driven by personal beliefs in the value of the NoS, rather than by curriculum requirements.

Students find learning about the nature of science challenging

Four out of the six teachers reported that, when teaching previous versions of the programme of study that included more content related to the NoS, students had found the ideas challenging. Alan stated that content related to the NoS is '*intellectually hard*' and that '*very many adults* [and] *many politicians*' struggle with concepts related to the nature of scientific knowledge. In particular, a number of the teachers argued that ideas related to the NoS were particularly challenging for lower-achieving students. Dawn suggested that, while material on the NoS provided a good context in which to stretch high achievers, the abstract concepts related to the nature of knowledge were challenging for lower-achieving students to engage with. She described the case of a question that required students to evaluate the extent to which the theory of natural selection was supported by evidence and reported that lower-achieving students struggled to address the form of the question. Ethan argued that, while some students found learning about the NoS engaging, others struggled to see the relevance of the material. He argued for the importance of contextualising abstract concepts in concrete situations and making use of historical detail to make lessons more engaging.

In general, while the teachers mourned the loss of opportunities to teach about the NoS, the reduced requirement to teach less-able students about the NoS in the new curriculum was perceived as removing a challenging aspect of previous curricula (see Alan's comment in the *Supporting the teaching of the nature of science* section below).

Teaching and assessing the nature of science is challenging

Most of the teachers (five out of six) reported that they found teaching about the NoS challenging because it

requires different teaching approaches from those used to teach other content in the science curriculum and because it addresses complex and abstract ideas. Alan stated that NoS content '*has always been exceptionally problematic to assess fairly*' and that '*teachers find it very difficult*'. He went on to claim that, while planning a lesson focused on scientific knowledge, for example how metal oxides react with acids, was relatively straightforward for an experienced teacher, explaining and developing activities to support students' understanding of the difference between reliability and accuracy was more intellectually challenging. The perceived ambiguity of assessment criteria for material related to the NoS was reported as contributing to the challenge of teaching. Dawn argued that assessment criteria were often unclear and that she had insufficient guidance on the depth of answers that examiners expected on questions focused on the NoS. By contrast, in a previous version of the curriculum, Ethan reported that the criteria for assessments focused on the NoS had become formulaic and the questions had become an exercise in '*hoop jumping*'.

Teachers interpret curriculum statements and teach about the nature of science in a variety of ways

In order to investigate teachers' interpretations of curriculum statements related to the NoS, the participants were asked to describe their understanding of, and approach to, teaching one objective: '*Students should be taught so that they develop understanding and first-hand experience of … the power and limitations of science*' (DfE, 2015: 5). For most of the teachers (Beth, Claire, Dawn and Ethan), the power of science referred to particular technological advances such as cloning or antibiotics. Ethan additionally linked the power of science to an approach to collecting and using data:

> *The power of science, that's scientists collecting evidence over a long period of time, modelling that evidence in a suitable way in order to catch the attention of those particular people and they've been able to influence their decision in a positive way.* (Ethan)

By contrast, the teachers' interpretations of the term '*limitations*' were more varied and are summarised in Table 2.

The responses listed in Table 2 demonstrate the differing ways in which a curriculum statement related to the NoS can be interpreted. The teachers described a number of different approaches to teaching about the power and limitations of science in their classroom. Alan reported that he had a strong personal interest in the relationship between science and society and described how he situated abstract ideas in a particular context to make them more engaging for students. For example, when describing the factors that cause people to come to accept or reject scientific models, he suggested using the context of the most recent (2016) presidential campaign in the United States to discuss how social and political factors can affect the manner in which scientific ideas are portrayed. Beth suggested an approach in which students are introduced to several different historical models of a concept, such as different constructions of how traits are inherited, in order to provoke a discussion on how the availability of evidence affects the acceptance of different models. Claire described an activity in which she asked her students to propose an argument, and then consider the evidence that they would require to convince other students to accept their proposition, before describing how changes to the available evidence had led scientists to revise their model of the atom.

Table 2 Participating teachers' interpretations of the term '*limitations of science*'

Teacher	Interpretation of the term '*limitations of science*'
Alan	Limitations are linked to the challenges of using scientific data to promote environmental and social change. Science lessons should include a discussion of '*why is the world finding it so difficult to do anything about this issue* [global warming] *and then you get into economics and politics and the nature of democracy*'.
Beth	Limitations are linked to the boundaries of scientific knowledge: '*The fact that there are many unanswered questions would be the limitations*'.
Claire	Limitations are linked to social factors that limit research; for example certain '*controversial ideas*', such as stem cell technology, receive limited funding.
Dawn	The limitations on science arise owing to scarcity of resources; for example, the '*technology available to use, money as well is a big factor, and time*'.
Ethan	Limitations refers to features of experimental approaches: '*We'll collect this evidence, but is it reliable, … why can't we a hundred per cent say that this is completely true, and you talk about the way experiments are designed and the equipment we use*'.
Fiona	Limitations refers to society's inability to solve problems with technology, for example, '*maybe teaching about the advancement of medicine, the limitations of medicine*'.

Teachers need additional support for teaching about the nature of science

The teachers were unanimous in a call for additional support for the teaching of the NoS. Alan, who had 26 years of teaching experience, reported that he had received no training on material related to the NoS in his degree or teacher-training course and had chosen to read around the topic because of a personal interest in the NoS. Claire, who trained on a school-based teacher-training programme, reported that she had received little input on pedagogies for supporting students' ideas about the NoS. Fiona argued that approaches used in past curricula, for example essays as a form of assessment of students' understanding of the NoS, could be effective for delivering the current programme of study but would require '*a lot of relearning and different teaching skills*'. She suggested that expecting teachers to pick up knowledge about the NoS through independent study was unlikely to have a significant impact and recommended that additional training should be made available. All the teachers described a lack of available resources to support their teaching about the NoS. Ethan reported that it was difficult to find definitions for keywords related to the NoS and cited the word '*power*' in the phrase '*power of science*' as an example of an ambiguously defined term.

Supporting the teaching of the nature of science

The findings of this small-scale study suggest that, in one secondary school science department in England, science teachers feel that the pressures of a content-heavy curriculum have resulted in fewer opportunities to teach students about the NoS. All six teachers acknowledged the value of teaching about the NoS and expressed regret that time to teach this material had been curtailed in the current curriculum. However, the teachers also described the difficulty of teaching challenging concepts related to the nature of scientific ideas. Alan summarised the mixed feelings expressed by the participants:

> *That part of the curriculum has always been exceptionally problematic to assess fairly, and also, it's actually very difficult, to teach and it's difficult to teach because, intellectually, students find it very difficult, and teachers find it very difficult, and so from the point of view of my job, I am not unhappy that it is has gone. From a more rounded point of view, as somebody who is very interested in the place of science in society, I'm sad that it's gone.* (Alan)

The data collected describe one science department eager to support their students to learn about the NoS but struggling to find time to address the topic amid the pressures of a content-heavy key stage 4 curriculum.

While teachers can do little to increase the curriculum time available to teach about the NoS, it is important that a balance is struck between teaching about science as a product, the content of science, and the processes used to generate scientific knowledge (Taber, 2017). Despite the pressures of the current curriculum, it is important for teachers to include brief sections of lessons that explain the nature of scientific knowledge and processes. There is a need for:

- additional resources to support teachers' understanding of the NoS;
- teaching materials designed to support lower-achieving students' understanding of the NoS;
- novel approaches for supporting and assessing students' understanding of the NoS.

It has been observed that no consensus view of the NoS exists among philosophers of science and hence Irzik and Nola (2011) have suggested that students should be introduced to a model of the NoS that acknowledges areas of greater and lesser agreement. Emphasising this principle would ensure that teachers go beyond promoting a single interpretation of a curriculum statement. For example, when teaching about the limitations of science, a teacher might introduce a scientistic interpretation, which argues that the scientific method can be applied to social and ethical problems, but also models of the NoS that argue the scope of science is more limited. This approach may allow teaching to be differentiated: lower-achieving learners could be asked to largely engage with areas of greater consensus while higher achievers could be challenged by discussing topics in the NoS that are less settled. At a time when students are likely to encounter attacks on established scientific claims in the media, it is more important than ever that science teachers take opportunities to teach about the nature of scientific claims and present a balanced view of the NoS.

References

Abd-El-Khalick, F. and Lederman, N. G. (2000) Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, **22**(7), 665–701.

Ball, S. J., Maguire, M. and Braun, A. (2012) *How Schools do Policy: Policy Enactments in Secondary Schools*. Abingdon: Routledge.

Benson, G. (1989) Epistemology and science curriculum. *Journal of Curriculum Studies*, **21**(4), 329–344.

Clermont, C. P., Borko, H. and Krajcik, J. S. (1994) Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. *Journal of Research in Science Teaching*, **31**(4), 419–441.

DfE (2015) *National Curriculum in England: Science Programmes of Study*. London: Department for Education.
Gayford, C. (2002) Controversial environmental issues: a case study for the professional development of science teachers. *International Journal of Science Education*, **24**(11), 1191–1200.
Hughes, G. (2000) Marginalization of socioscientific material in science-technology-society science curricula: some implications for gender inclusivity and curriculum reform. *Journal of Research in Science Teaching*, **37**(5), 426–440.
Irzik, G. and Nola, R. (2011) A family resemblance approach to the nature of science for science education. *Science and Education*, **20**(7), 591–607.
Ratcliffe, M. (1997) Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education*, **19**(2), 167–182.
Taber, K. S. (2017) Reflecting the nature of science in science education. In *Science Education: An International Course Companion*, ed. Taber, K. S. and Akpan, B., pp. 23–37. Rotterdam: Sense Publishers.
Taber, K. S. (2000) Case studies and generalizability: grounded theory and research in science education. *International Journal of Science Education*, **22**(5), 469–487.
Taber, K. S. and Brock, R. (2018) The nature of science and the nature of school science. In *ASE Guide to Secondary Science Education*, 4th edn, ed. Banner, I. and Hillier, J. pp. 14–25. Hatfield: Association for Science Education.

Richard Brock taught secondary physics and is currently a Postdoctoral Fellow in Science Education at King's College London. Email: richard.brock@kcl.ac.uk
Keith S. Taber is Professor of Science Education at the University of Cambridge. He has taught physics and chemistry in comprehensive schools and a further education college, and has worked in science teacher education. Email: kst24@cam.ac.uk